THE OPPOSITION EFFECT

by

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Solar system objects, unlike all other objects seen in the night sky, are only discernible by the sunlight reflected from their surfaces or from the top of the upper deck of the clouds in their atmospheres. Therefore, they exhibit a set of optical properties that are distinct from objects which have their own internal energy source such as the sun and stars.

The light reflected from a solar system body that is illuminated by the sun and observed from the earth undergoes a variety of geometrical and physical processes on its path from the sun to the object and back to the earth.

It has been known for more than a century that the intensity of this light when reflected from a solid surface varies as a function of the phase angle, the angle defined by the sun-object-earth, at the time of observation. One source of this variation is the obvious geometrical effect caused by the fact that the object under observation is never fully illuminated except when the phase angle is zero degrees. However even when a correction is made for this 'defect of illumination', the intensity of the reflected light is observed to increase non-linearly as the phase angle decreases toward zero degrees. It is this non-linear surge in reflected light seen when an object is observed at small phase angles that is called the opposition effect.

Research has revealed that the opposition effect is due to several independent geometric and physical processes acting in combination. The cumulative size of the opposition effect from all of these processes is a function of the particle size, albedo, and the packing density of the regolith material. The principal geometric process that contributes to the opposition effect is called the shadow hiding hypothesis and the principal physical process is called coherent backscattering hypothesis.

The Shadow Hiding hypothesis

As sunlight falls on a particulate planetary surface the particles which comprise the regolith will cast shadows on one another. An earth based observer will see a combination of, sunlight reflected from the particles on the surface, light reflected from a particle after having been transmitted through one or more grains prior to reflection, light reflected from a grain after diffraction around the edge of one or more particles, and the portions of the surface that are lying in shadow and are only illuminated by multiply scattered light. The shadow hiding model posits that the size of the opposition effect will increase as the albedo of the particles gets smaller. This effect can be approximated by the following expression.

$$B(g)=\frac{B_0}{1+(\frac{1}{h})\tan(\frac{g}{2})}$$

where

B_0 is the amplitude of the opposition effect

h=-the width of the opposition effect

and

g== the phase angle of the observation.

This expression has been used to model the opposition effect down to phase angles as sm **all** as a few degrees. The size of the opposition effect, 11., is a function of the single scattering al bedo and the angular scattering function of the regolith particles.

The Coherent Backscattering Hypothesis

The shadow hiding model of the opposition effect dots not predict a strong opposition surge for highly reflective particulate media. However, opposition effects arc observed in such materials in the laboratory and these effects arc most pronounced at phase angles between 0° and 1[1]. The principal cause of the opposition surge that is seen in highly reflective materials is the phenom enon of' coherent constructive interference between light rays that are multiply scattered in the planetary regolith.

The coherent backscattering hypothesis argues that any two light rays that enter a medium at different points and travel the same path except in opposite directions will constructively interfere as the difference in total path length traveled by the two rays approaches the wavelength of the light. In this case, the rays will constructively interfere and a pronounced opposition effect will be seen. The angular width of this peak is related to the wavelength of the illuminating light, the index of refraction of the particles, and the packing density of the particles. Theoretical models estimate that the full width half maximum of the opposition effect caused by coherent backscattering is $\frac{\lambda}{2\pi D}$, where λ is the wavelength of the light impinging on the surface and D is the photon mean free path in the medium.

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